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3 CMP Polishing Heads Retaining Ring Groove Design for Microscratch Reduction

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Background of Invention

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8 1) Field of the Invention

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Embodiments of this invention relate to Chemical Mechanical Polishing (CMP) methods and machines, and particularly to retaining ring designs for CMP heads and more particularly to retaining ring designs with curved grooves for reducing microscratches on semiconductor structures.

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15 2) Description of the Related Art

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In semiconductor fabrications, the chemical-mechanical polish (CMP) technique is widely used for the global planarization of semiconductor wafers that are used for the fabrication of VLSI (very large-scale integration) and ULSI (ultra large-scale integration) integrated circuits.

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FIGS. 1A and 1B are schematic diagrams showing a conventional CMP machine. The CMP machine comprises a polishing table 10 on which a polishing pad 12 is

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1 layered, a polishing head 14 for holding a semiconductor wafer 16 in position, and a nozzle
2 18 for applying a mass of slurry to the semiconductor wafer 16 during the CMP process.

3 FIG. 1C shows a respective view of the structure inside of the polishing
4 head 14. As shown, the polishing head 14 includes an air-pressure means 20 which applies
5 air pressure to a wafer loader 22 used to hold the wafer 16. In addition, a retainer ring 24 is
6 mounted around the loader 22 and the wafer 16, which can retain the wafer 16 in fixed
7 position during the CMP process. Moreover, a cushion pad (not shown) is placed between
8 the wafer 16 and the loader 22.

9 A problem of current chemical-mechanical polish (CMP) machines and
10 process is the micro-scratches formed on the substrate during the CMP process.

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13 The importance of overcoming the various deficiencies noted above is
14 evidenced by the extensive technological development directed to the subject, as
15 documented by the relevant patent and technical literature. The closest and apparently
16 more relevant technical developments in the patent literature can be gleaned by considering
17 US 6,386,962(Gotkis et al.) that shows a wafer carrier with retainer ring for a chemical-
18 mechanical polish (CMP) apparatus.

19 US 6,527,624 B1(Tollers et al.) shows a retaining ring.

20 US 6,110,025(Williams et al.) teaches a retainer ring with passages.

1 US 6,293,850 B1(Lin et al.) shows retaining ring with slurry passages
2 at the bottom of the retainer ring.

3 US 6,224,472 B1(Lai et al.) teaches a retaining ring with channels.

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5 However, the retaining rings can be further improved.

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Summary of the Invention

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It is an object of example embodiments of the present invention to provide a retaining ring for use in a chemical-mechanical polish (CMP) machine.

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It is an object of example embodiments of the present invention to provide a CMP method and a retaining ring having channels with rounded contour or rounded corners or curved surfaces for use in a chemical-mechanical polish (CMP) machine.

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An example embodiment of the present invention provides a retaining ring which is characterized as follows. A CMP retaining ring, comprising:

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an inner peripheral surface;

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an outer peripheral surface;

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a lower surface adapted to contact and depress an upper surface of a polishing pad during chemical mechanical polishing of a lower surface of a substrate; the

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substrate is contained within the inner peripheral surface of the retaining ring during

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chemical mechanical polishing; and

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at least a groove on the lower surface of the retaining ring and extending

1 from a position at or adjacent the inner peripheral surface of the retaining ring, to a
2 position at or adjacent the outer peripheral surface of the retaining ring;

3 at least a portion of the groove has a rounded contour.

4 In another aspect, the groove has a semicircle profile.

5 In another aspect, the groove has a semicircle profile and the groove
6 has a rounded top corner adjacent to the lower surface of the retaining ring.

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8 An example embodiment of a process of the invention is described as
9 follows. A process for chemical-mechanical polish (CMP) a wafer comprising:

10 the wafer is disposed within a polishing head with the deposition layer
11 facing a polishing table; the wafer is retained within the polishing head by a retainer ring,
12 and

13 at least a portion of the groove has a rounded contour;

14 supplying a slurry to the polish table and/or polish head;

15 rotating the polishing table and spinning the polishing head to

16 chemically polish the wafer.

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18 Another aspect further includes: forming a deposition layer on the
19 surface of the wafer and chemical mechanically polishing the deposition layer.

20 Another aspect further includes: the groove has a semicircle profile.

1 Another aspect further includes: the groove has a semicircle profile
2 and the groove has a rounded corner adjacent to the lower surface of the retaining ring.

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4 The above advantages and features are of representative embodiments
5 only, and are not exhaustive and/or exclusive. They are presented only to assist in
6 understanding the invention. It should be understood that they are not representative of all
7 the inventions defined by the claims, to be considered limitations on the invention as
8 defined by the claims, or limitations on equivalents to the claims. For instance, some of
9 these advantages may be mutually contradictory, in that they cannot be simultaneously
10 present in a single embodiment. Similarly, some advantages are applicable to one aspect of
11 the invention, and inapplicable to others. Furthermore, certain aspects of the claimed
12 invention have not been discussed herein. However, no inference should be drawn
13 regarding those discussed herein relative to those not discussed herein other than for
14 purposes of space and reducing repetition. Thus, this summary of features and advantages
15 should not be considered dispositive in determining equivalence. Additional features and
16 advantages of the invention will become apparent in the following description, from the
17 drawings, and from the claims.

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Brief Description of the Drawings

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The features and advantages of a retaining ring and methods thereof according to example embodiments the present invention will be more clearly understood from the following description taken in conjunction with the accompanying drawings in which like reference numerals designate similar or corresponding elements, regions and portions and in which:

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Figure 1A is a schematic top view of a chemical-mechanical polish (CMP) machine for performing a CMP process on a semiconductor wafer according to the prior art.

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Figure 1B is a schematic section view of the chemical-mechanical polish (CMP) machine of figure 1A according to the prior art.

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Figure 1C is a cross sectional view showing an inside structure of the polishing head used on the CMP machine of figures 1A and 1B according to the prior art.

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Figure 2A is perspective view of a retaining ring having rectangular grooves 204.

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Figure 2B is a close up perspective view a groove in a retaining ring having rectangular grooves 204 as shown in figure 2A.

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Figure 2C is a cross sectional view of a groove that has slurry particles that cause the problems as discovered by the inventors.

1 Figure 3A is perspective view of a retaining ring that has non-
2 rectangular grooves 304 according to an aspect of the invention.

3 Figure 3B is a close up perspective view of an embodiment where the
4 groove has a semicircle profile according to an aspect of the invention.

5 Figure 3C is a cross sectional view of a groove that has a semicircle
6 profile according to an aspect of the invention.

7 Figure 3D is a cross sectional view of a groove that has rounded or
8 curved or non-angular bottom corners and curved sidewalls 316 according to an aspect of
9 the invention.

10 Figure 3E is a cross sectional view of a groove that has rounded or
11 curved or non-angular bottom corners 311, rounded top corners 320 and slanted or sloped
12 sidewalls 322 according to an aspect of the invention.

13 Figure 3F is a cross sectional view of a groove 304F that has rounded
14 or curved or non-angular bottom corners and about vertical sidewalls 316 and a flat
15 bottom 316 according to an aspect of the invention.

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17 Figure 4A is perspective view of a retaining ring that has non-
18 rectangular grooves 404 and curved top corners according to an aspect of the invention.

19 Figure 4B is a close up perspective view of an embodiment where the
20 groove has curved top corners according to an aspect of the invention.

1 Figure 4C is a cross sectional view of a groove that has a semicircle
2 profile and curved top corners according to an aspect of the invention.
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1 **Detailed Description of the Preferred Embodiments**

2 **Introduction**

3 Referring now to the drawings and more particularly to Figures 2A,
4 2B, and 2C, there is shown a retaining ring 200 over which the aspects of the present
5 invention are an improvement. It is to be understood in this regard that no portion of
6 Figures 2A, 2B and 2C is admitted to be prior art as to the present invention. Rather, this
7 these diagrams are an effort to provide an improved understanding of some of the
8 problems that are overcome by the aspects of the invention.

9 Figure 2A is perspective view of a retaining ring 200 having rectangular
10 shaped grooves 204. The ring has a lower surface 201 (polishing surface or pad side
11 surface) that in operation faces the polish pad.

12 Figure 2B is a close up perspective view a groove 204 that has non-
13 curved corners or edges in the a retaining ring 200.

14 Figure 2C is a cross sectional view of a groove 204 that has slurry
15 particles or other debris 208 that cause the problems as discovered by the inventors.

16 Microscratches are a defect caused by the CMP process. Big particles
17 and/or dry slurry are causes of the microscratches. Big particle size can be control by
18 filtration in the supplier's factory and the dried slurry is hard material normally found the
19 in-house slurry delivery related components. The forming of dried slurry can occur when
20 the water vaporizes from the slurry droplet spilled on the surface of some polishing
21 machine components.

1 The inventors have found that the retaining ring in the chemical-
2 mechanical polish (CMP) machine is a source of dried slurry. As shown in figure 2C, the
3 corner of the groove of the wafer polishing head's retaining ring was found to accumulate
4 a few chunks of dried slurry. A purpose of these grooves is to allow the slurry flow in to
5 the wafer polishing head for efficient planarization process. Unfortunately, the design of
6 the current retaining ring grooves can cause slurry particles to accumulate and increase
7 micro scratches.

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9 **Example embodiments of the grooves of the invention**

10 Example embodiments of the grooves of the invention have at least a
11 portion of the groove or the surface adjacent to the groove is curved. Examples of
12 curvilinear portions of groove are: semicircle shaped grooves, arc shapes grooves, grooves
13 with rounded bottom corners, grooves with rounded top corners, grooves with curved
14 sidewalls, grooves with slanted sidewalls, and combinations thereof. The example
15 embodiment of the grooves reduce the buildup of dried slurry in grooves and thus reduce
16 microscratches.

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18 As shown in figure 3A, a chemical-mechanical polish (CMP) retaining
19 ring 300 comprises: an inner peripheral surface 303; an outer peripheral surface 302; and a
20 lower surface 301. The lower surface 301 is adapted to contact and depress an upper
21 surface of a polishing pad during chemical mechanical polishing of a lower surface of a

1 substrate contained within the inner peripheral surface of the retaining ring during
2 chemical mechanical polishing.

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4 The retaining ring can be economically and speedily fabricated through
5 the injection molding, casting or other molding processes. The mold can be built to contain
6 the sizable cavity with the retaining ring's net shape. The most commonly used materials
7 for retaining ring, normally but not limited to thermosetting or thermoplastic polymer, is
8 heated to highly plastic state and forced to flow into the cavity. The solidified molded part
9 or the retaining ring is removed from the cavity and sent for other finishing or shaping
10 processes.

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12 The retaining ring 300 has grooves 304 on the lower surface 301. The
13 grooves 304 preferably extend from a position at or adjacent the inner peripheral surface of
14 the retaining ring, to a position at or adjacent the outer peripheral surface of the retaining
15 ring. The cross sectional area of the groove can be constant or changes along the length of
16 the groove. Preferably, at least a portion of the groove 304 has a rounded contour.
17 Preferably the cross sectional shape of the groove is rounded or has rounded corners.
18 Preferably the cross section of the groove does not contain a portion (possibly other than
19 the top corner) where two flat areas meet at a angle, such as a 90 degree angle.
20 Preferably, the groove has a shape that reduces the amount of dried slurry and other
21 particles that accumulates in the groove during a polish operation.

1 The term “rounded” can mean: curved, or with curved parts: having
2 curved, not straight or angular, surfaces or edges.

3 The grooves may not have the same cross sectional area along the
4 length of the groove. The grooves can preferably have a depth between 2 and 15 mm.
5 From a top down view, the groove can have any shape, such as a straight shape as shown
6 in figure 3A or can be curved or some combination thereof .

7 Figure 3B shows a closer view of a preferred embodiment of the
8 invention where the groove 304C has an about semicircle profile.

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10 Figure 3C shows a cross sectional view of a groove 304C that has a
11 semicircle cross-sectional profile 310 with a radius 311. The grooves 304C have a
12 semicircle profile preferably with a radius 311 between 2 mm and 15 mm. The semicircle
13 profile of the groove helps prevent the slurry particles from accumulating in the groove.

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15 In the aspect shown in figure 3D, the groove 304D has curved sidewalls
16 316 and a rounded bottom corner 312 and a flat bottom 314. The grooves can have at
17 least one rounded corner. The grooves have rounded corners/edges 312 adjacent to the
18 bottom 314 of the grooves. The rounded corners, edges or surfaces 312 can prevent slurry
19 form accumulating in the groove.

20 In an aspect, the retaining ring has grooves with rounded top edges
21 adjacent to the lower surface 301 of the retaining ring.

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Referring to figure 3E, an aspect is shown where the groove 304E has a rounded top corner 320 near the lower surface of the ring. The groove has a sloped sidewall 322. The groove has a slanted contour. Slanted means the sidewall has a least a section that is not at about a 90 degree angle with the lower surface 301 of the ring. The groove has a rounded bottom corner 311 and a flat 316 bottom. The bottom can be flat or curved.

In an aspect shown in figure 3F, the CMP retaining ring has a groove has with about vertical sidewalls 330 and an about horizontal flat bottom 316 and at least one rounded corner 311 between the vertical sidewalls 330 and the horizontal bottom 316. The grooves can have a width between 1 and 30 mm.

Figure 4A shows another embodiment where the groove 404 has top corner or edge with a curved shape.

Figure 4B shows a perspective view of the groove 404 with the rounded top corner 420. In the aspect shown in figure 4B and 4C the groove has a semicircle profile 410 and top rounded corners 420.

Figure 4C shows a preferred embodiment of the invention of a groove 404C with rounded top corners 420 and a semicircle profile 410. In an option, the rounded top corners 420 can have the shape of a arc of a circle having a radius 413. In an option, the semicircle profile 410 can have radius 411.

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The retaining ring can have other channels on the lower surface. Also, the lower surface of the retaining ring can further comprise a plurality of protrusions and recesses or a mixture of both. In addition, the retaining ring can have other passages thru the ring such as a passage connecting the grooves to the top side of the ring. See e.g., US 6,527,624 B1.

It will be understood that CMP retaining rings embodiments of the invention may be advantageously used with any type of CMP polishing system, pad material and/or polishing slurry, such as where the lower (or pad-side) surface of the retaining ring contacts the polishing pad during polishing. Examples of suitable CMP slurries include, but are not limited to, Cabot "SS25", Cabot "SS12".

It should be noted that the retaining ring and wafer carriers of the present invention may be used with any suitable CMP systems such as linear CMP apparatus or rotary CMP apparatus.

Process using the retaining ring of aspects of the invention

The retaining rings of the aspects of the invention can be used in a process to CMP a substrate. The substrate is preferably a wafer with layers formed or deposited thereover. The layers can be insulating and/or conducting layers. The insulating layers can be comprised of oxide, (e.g., oxide made from tetraethylorthosilicate (TEOS))

1 or low-k materials. The conductive layers can be metal layers such as copper alloys, or
2 Aluminum alloys.

3 A process for chemical-mechanical polishing a wafer comprises the
4 following.

5 The wafer is disposed within a polishing head with the deposition layer
6 facing a polishing table. The wafer is retained within the polishing head by a retainer ring.

7 The retaining ring is a ring according to an aspect of the invention
8 describe above. For example, at least a portion of the groove has a rounded contour.

9 We supply a slurry to the polishing table or the polish head.

10 We move the polishing table and/or the polishing head to chemically
11 polish the wafer. Preferably, we rotate the polishing table and spin the polishing head to
12 chemically polish the wafer. Preferably the polish table has a polish pad thereover and the
13 polish pad polishes the substrate.

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16 In the above description numerous specific details are set forth in order
17 to provide a more thorough understanding of the present invention. It will be obvious,
18 however, to one skilled in the art that the present invention may be practiced without these
19 details. In other instances, well known process have not been described in detail in order
20 to not unnecessarily obscure the present invention.

1 Given the variety of embodiments of the present invention just
2 described, the above description and illustrations show not be taken as limiting the scope
3 of the present invention defined by the claims.

4 While the invention has been particularly shown and described with
5 reference to the preferred embodiments thereof, it will be understood by those skilled in
6 the art that various changes in form and details may be made without departing from the
7 spirit and scope of the invention. It is intended to cover various modifications and similar
8 arrangements and procedures, and the scope of the appended claims therefore should be
9 accorded the broadest interpretation so as to encompass all such modifications and similar
10 arrangements and procedures.

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